Agricultural goods and bads: Essays on agriculture and environmental externalities

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ACADEMIC DISSERTATION

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Abstract

This dissertation examines the economics of agricultural production and related environmental externalities. In the context of this study, environmental externalities are market failures caused by unintentional outputs of agricultural production. These outputs may be characterized as public goods/bads and they are approached using a joint production framework. The examined externalities are biodiversity benefits, nutrient runoff damages, and costs related to greenhouse gas (henceforth GHG) emissions and climate change.

The main objective of this thesis is to study the welfare impacts of the production of different agricultural commodities, especially bioenergy, and agricultural production methods, when environmental externalities are taken into account. Also the costs of increasing or decreasing the unintended environmental public goods or bads causing the externalities are examined. The dissertation consists of an introductory article and four separate studies. In the first three studies, the focus is both on optimization of agricultural joint production systems, and on studying the welfare and environmental impacts of different policies. The last paper examines a case where a public environmental bad, namely climate change, of other anthropocentric/economic activities impacts agricultural production and thus it serves as an input factor of agricultural production.

The dissertation shows that the scope of an agricultural externality often depends on local characteristics and underlying assumptions, such as those related to land use, the existence of adaptation measures, and the utility and damage functions. The studies also indicate that policies targeted to agri-environmental externalities should be designed holistically for example by taking into account entire landscapes or sectors, but at the same time by relying on heterogenous policies within these entities.

Keywords: environmental externality, public good/bad, agriculture, bioenergy, biodiversity, nutrient runoff, GHG emissions, climate change.

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List of original essays

In the introductory article the listed articles are referred to using Roman numerals **I-IV**.

I. Saikkonen, L., Herzon, I., Ollikainen, M., Lankoski, J. 2014. Socially optimal drainage system and agricultural biodiversity: A case study for Finnish landscape. Journal of Environmental Management, 146, 84-93.

II. Saikkonen, L., Ollikainen, M., Lankoski, J. 2014. Imported palm oil for biofuels in the EU: Profitability, greenhouse gas emissions and social welfare effects. Biomass and Bioenergy, 68, 7-23.

III. Saikkonen, L. 2019. Economics of bioenergy production from agricultural biomass with application to herbaceous field crops and lignocellulosic bioethanol. Manuscript.

IV. Leppänen, S., Saikkonen, L., Ollikainen, M. 2016. Impact of Climate Change on Cereal Grain Production in Russia. Manuscript.

Author's contribution

Liisa Saikkonen is the lead author in essays I, II and III. She was the main contributor to all aspects (1. research idea and question, 2. theoretical approach, 3. data collection, 4. empirical modeling and simulation, 5. writing and interpreting the results, 6. Finalization and revision) of these papers. Simo Leppänen was the lead author of Essay IV, where Liisa Saikkonen contributed to all other phases except to forming the research idea and question. Liisa Saikkonen was also solely responsible for writing the introductory chapter of the thesis.

Contents

1 Background

In economics, an externality can simply be defined as a cost or a benefit that affects a party who did not choose to incur that cost or benefit (Buchanan and Stubblebine, 1962). Baumol and Oates (1988) state that an externality should further be defined as an unintended impact that is initially not taken into account in the objective of the party that causes the impact. Thus an externality is not remunerated to the provider or the recipient. A pure public good is a good which has two characteristics; non-excludability and non-rivalry. A good is non-excludable if the marginal cost of an additional party consuming the good is zero. For a non-rivalrous good it holds that the cost of excluding an individual from the benefits of consuming the good is infinite (Stiglitz, 1974). An externality usually results from the unintentional production of public goods or bads[1]. Due to their characteristics, the unregulated markets of public goods and bads are non-existent or imperfect. In such markets private firms do not face full benefits or costs for a public good/bad which they have produced, and their incentives to control its' production are insufficient.

In addition to food and fiber production, agriculture has pervasive impacts on the environment. These impacts often share public good characteristics. Thus, many agricultural goods or bads, like nutrient runoff, GHG emissions and changes in biodiversity pose an externality cost or benefit, that results by means of an unintentional agricultural byproduct. Such production systems can be studied using a joint production framework where multiple outputs are produced interdependently, so that at least one of these outputs is an environmental good or bad. However, the theory of joint production itself does not have to imply the production of a public good (Samuelson, 1969), but herein the theory is used mainly to study joint production where at least one of the outputs is a

[1] Herein the term "bad" is used to define an output that causes disutility to its consumers.

public good or bad (articles I-III). In the last article of this thesis (V), the definition of joint production system is expanded to include systems that use inputs interdependently, so that at least one of the inputs is an unintentional environmental public good or bad that is caused by some other economic activity.

There has been a great deal of discussion on the causes for jointness in production (see for example Buchanan and Stubblebine (1962); Shumway et al. (1984, 1988)). The most traditional view may be that jointness exists only with non-allocable resources, so that one is not able to allocate input resources separately for each output, but they are produced jointly using the same input (Beattie et al., 1985, p.179-222). Shumway et al. (1984) have argued that especially in the case of agricultural production there are other causes for jointness, such as fixed input use and joint production environment or technology. Here a traditional definition of joint production is applied; jointness is caused by all non-allocable inputs regardless if they are fixed. It is also assumed that the production technologies are not joint and thus production can be defined by separate production functions, where the inputs can be allocable or non-allocable among the technologies (Beattie et al., 1985, p.218). In the expanded model of joint production an exogenous level of environmental public good or bad, namely climate change, is used as a production input (article IV). In this case it is assumed that the producer allocates other inputs to adapt to a long-term change in a level of an exogenous input, whereas in the short term the adaptation measures are more limited. It is assumed that the production function is not additively separable for the exogenous input, meaning that an absolute impact of this input on the output is indefinable, because the impact depends also on the other inputs.

The main theme of this thesis is to study the production and consumption of agricultural commodities and related environmental externalities, using the joint production theory. The theoretical framework of joint production is defined in this introductory article and then applied to agricultural supply chains in the four separate studies of this thesis. The environmental externalities studied in this dissertation are biodiversity benefits, nutrient runoff damages, and costs related to GHG emissions and climate change. We consider the question of optimal agricultural production and also the policies to optimize production in existence of these externalities (articles I-IV). Further, we study the costs to increase or decrease a public good/bad that causes the externality, when the optimal production cannot be defined due to the lack of convincing cost or benefit definition (articles I-II).

2 The theoretical framework of joint production

2.1 Basic framework of joint production

The basic framework presented here is based on joint production theory (see, for example Beattie et al. (1985, p.179-222,82-83)) and theory of externalities (see, for example Cornes and Sandler (1996, parts II and III)). Herein the framework is defined for two inputs (allocable and non-allocable), and two outputs (intended commodity and unintended output), but in the separate studies I-IV the model is applied for other input and output numbers.

Consider a firm that produces two outputs. These outputs (and their quantities) are denoted by y_c and y_u. The output y_c is an intended commodity, and output y_u is an unintended impact that results from the production of y_c. It is assumed that the market for intended commodity is perfect. Whereas, the unintended output can be identified as a public "good" or "bad" based on it's impact on the utility of the consumers. Therefore this impact on the utility is an externality resulting from the production of traditional commodity.

Assume that the intended output y_c is produced using an allocable input factor x_a and a non-allocable input factor x_n. The allocable input factor can be allocated to a certain output so that the total amount of input used in the production is the amount of input used to produce intended commodity $x_a = x_{ac}$. Here we expand the definition of allocable input factor to include also the inputs that do not affect the unintended output. The non-allocable input cannot be explicitly allocated to separate outputs, but each individual unit of a non-allocable input factor is used in the production of both outputs. Therefore the production of an intended output may result in production of an unintended output.

In essays I-III we mainly assume that all input factors are non-allocable, such as fertilizer used for crop production that also results in nutrient runoff, or biomass (type and quantity) used in bioenergy production that also results in greenhouse gas emissions.

However here in the theoretical framework of joint production it is demonstrated, how the non-allocable inputs and resulting unintended outputs affect optimal production. The production technologies are assumed non joint and thus outputs produced by the firm can be written as separate production functions of input factors

$$y_c = f_c(x_{ac}, x_n) \tag{1}$$

$$y_u = f_u(x_n). \tag{2}$$

The production of an output poses costs to the firm. The cost function of a firm with respect to outputs is denoted by $C(y_c, y_u)$, which is defined as the minimum cost to produce the output quantities y_c and y_u. The unusual feature of cost minimization for non-allocable inputs, compared to only allocable inputs, is that the cost minimizing use of inputs for intended output y_c is affected by output y_u that is produced using the same non-allocable input (Beattie et al., 1985, p.216-221). Therefore the cost minimizing use of an input x_a for production of y_c can be affected by y_u that is produced using the same unallocable input x_n, even though the allocable input x_a is used only for the production of commodity output y_c. If the unintended output causes an externality that is not taken into account in the market, the production of an intended commodity is not affected by the unintended output through production costs, because the firm is indifferent about the produced quantity of the unintended output.

The utility function of a consumer with respect to outputs is given by $U(y_c, y_u)$ and the social welfare defined as total aggregated surplus of the producers and consumers is

$$\Pi^A = U^A(y_c^A, y_u^A) - C^A(y_c^A, y_u^A) \tag{3}$$

where y_c^A, y_u^A, $U^A(y_c^A, y_u^A)$ and $C^A(y_c^A, y_u^A)$ are the aggregate production outputs, utility, and costs of all individuals in the market respectively. The equilibrium for a perfect market, when the utility impacts of the unintended output, aka externalities, are taken into account is defined by maximizing social welfare

$$\max_{y_c^A, y_u^A} \Pi^A(y_c^A, y_u^A) \tag{4}$$

When the externalities are taken into account in the market equilibrium production is at the socially optimal level. At the socially optimal level, social welfare, including total surplus resulting from the consumption and production of conventional commodities, and unintended public goods and bads, is maximized. Assuming that the cost and utility functions are differentiable, social welfare is maximized when marginal social costs equal marginal social benefits, and the equilibrium market price and optimal policy instruments such as taxes reflect these marginal social costs and benefits.

Now assume that the true aggregate externality of the public good or bad, aka unintended output, cannot be adequately defined, or that the government/social planner is unable to regulate their markets. Therefore unintended public good or bad and its utility impacts are not taken fully into account in the market equilibrium, and thus the production is at a socially suboptimal level. If the unintended output is not at all accounted for in the market, then the market equilibrium is defined by maximizing the total aggregate surplus resulting from the production and consumption of the intended output

$$\max_{y_c^A} U^A(y_c^A) - C^A(y_c^A) \tag{5}$$

Assuming that the aggregate cost and utility functions are differentiable, the total surplus resulting from production and consumption of the commodity output is maximized when marginal production costs equal marginal utility, and the market price equals these marginal values. The production of an unintended output y_u^A can be defined ex-post according to cost minimizing input use leading to total surplus maximization with respect to intended output y_c^A.

Now, we move from the market level to a case of a single firm, and also explain how the introduction of a price for an externality affects the production of a single firm. The profit maximization problem of a single firm operating in a competitive market where the externalities caused by the unintended output are not taken into account is

$$\max_{y_c} p_c y_c - C(y_c) \tag{6}$$

where p_c is the market price of the commodity output and the price of the unintended output causing the externalities is zero. Again the cost function is written only as a function of intended commodity output, since the production of an unintended output is an ex-post value defined by the cost minimizing use of input factors to produce commodity output that maximizes firm profits.

Finally we take the externalities resulting from an unintended commodity into account by introducing a price p_u on them. Assuming that the aggregated cost and utility functions are differentiable, social welfare (eq. 3) is maximized when the price of an unintended output is equal to its aggregated marginal cost and utility. For negative externalities this price could be for example a pigouvian tax ($p_u = \text{tax} < 0$). Now the profit maximization problem of a firm is

$$\max_{y_c, y_u} p_c y_c + p_u y_u - C(y_c, y_u) \tag{7}$$

In this case the revenue and costs depend also on the initially unintended commodity y_u and therefore it is taken into account in the profit maximization. Now the use of both input factors is defined as the cost minimizing level of input factors to produce outputs that maximize firm profits when the price of an unintended commodity is unequal to zero.

2.2 Joint production and imperfect competition

Next the joint production model is defined for an imperfect market, where one consumer (e.g. refining firm) has monopsony power over output producers. Therefore this consumer can affect output prices, and also indirectly the use of input factors that are used to produce outputs. Monopsony faces the market supply curve and usually buys less than a competitive firm in order to reduce the price of the product. Thus the production of outputs and the use of input factors is usually lower than in the case of a perfect market. Assuming that the aggregate costs of the producing firms C^A are differentiable with respect to outputs, the monopsony profit maximization problem can be written as

$$\max_{y_c^A, y_u^A} U(y_c^A, y_u^A) - \frac{\partial C^A}{\partial y_c^A} y_c^A - \frac{\partial C^A}{\partial y_u^A} y_u^A \tag{8}$$

where the consumer of the aggregated outputs $\mathbf{y_c^A}$ and $\mathbf{y_c^A}$ maximizes utility $U(y_c^A, y_u^A)$ (e.g. revenue of a refining firm) given the marginal aggregate costs of the producers.It is also possible to define a case where one of the jointly produced outputs is sold at a perfect market by setting a marginal cost $\frac{\partial C^A}{\partial y_c^A}$ or $\frac{\partial C^A}{\partial y_u^A}$ to equal exogenous market price for that output.

2.3 Public good or bad as a production input

Finally consider a modified version of a one output model where there are two input factors that affect one output. One of these inputs is an exogenous input factor that has an impact on the production and profitability of a firm, and this impact can be perceived as an externality resulting from production and consumption of other parties. The output production in such case is defined by

$$y = f(x_1, x_2) \tag{9}$$

where x_1 is now a production input that can be controlled by the firm, and x_2 is an exogenous input. Such input can be perceived as unintended output of other economic actors, and thus this input can be further defined as public good/bad that causes externality via the production function. We assume that the production function is additively inseparable and thus the absolute impact of an input factor on an output cannot be explicitly defined. However, the firm can adapt to the exogenous input x_2, such as climate (change), by optimizing the level of controllable input x_1.

3 The subject matter of the thesis

3.1 Joint production in agricultural supply chains

In the first three essays/articles of this dissertation (I,II,III) biodiversity benefits (I), social costs of GHG induced climate change (II,III), and nutrient runoff damages (I) are the studied externalities of agricultural production, and production of bioenergy from agricultural raw materials. In papers (II and III) agricultural production and bioenergy production together form an agricultural supply chain, whereas in essays (I and IV), agricultural supply chain consists only of agricultural production. In the last essay (IV) climate change can be identified as a public good/bad input that affects production of a joint product, namely cereal grain yield. The inputs and outputs of agricultural supply chains of the articles are given in Table 1. The commodity outputs of production systems are cereal grains (I,IV), oil seeds (I,II), palm oil (II), agricultural biomass (III) and bioenergy (II,III). In the papers II and III the supply chains consist of agricultural production and bioenergy production from agricultural raw material, and thus at least some of the agricultural products are used as intermediate inputs in bioenergy production.

The inputs of studied agricultural joint production systems are fertilizer use, drainage system and crop choice (I), feedstock choice and feedstock quantity (II), biomass choice and biomass quantity (III), and climate/weather, fertilizer use and land use (IV). In papers II and III the use of fertilizer and other agricultural inputs is assumed fixed per an unit of biomass/feedstock. In these studies the supply of biomass/feedstock and public goods and bads is limited by spatial factors such as land availability and distance.

Table 1: Descriptions of the studies

Study	**Public good/bad**	**commodity goods**	**Input factors**	**Method**
I	biodiversity, nutrient runoff	grain crops and oilseeds	drainage choice, fertilization use, crop choice	optimization, simulation, cost-approach
II	GHG emissions, climate change	biofuel produced from oil palm and oilseeds	feedstock choice, feedstock quantity	optimization, simulation, cost-approach
III	GHG emissions, climate change	bioenergy produced from agricultural biomass	biomass choice, biomass quantity	optimization, simulation
IV	Climate change	grain crops	fertilizer use, land use	fixed effect and LD estimation, simulation

The main causes of GHG emissions in biofuel production from agricultural biomass in studies II and III are agricultural input use and land use change. The GHG emissions related to land use change may be significant, especially if biofuel is produced from imported feedstocks such as palm oil. Therefore the emissions of biofuels made from agricultural biomass may be even higher than for fossil fuel, depending on the origin and on the biomass (Dumortier et al., 2011). However, the use of lignocellulosic crops or lignocellulosic parts of crops in biofuel production is considered to result in lower emissions than the use of edible biomass in biofuel production. This maybe even more so in the future, because the technology related to lignocellulosic ethanol production is constantly evolving (Lynd et al., 2017).

In Finland, a major cause of nutrient runoff resulting from crop production is fertilizer use. Nutrient runoff as a source of environmental externality has drawn a lot of attention in Finland mostly due to eutrophication of the Baltic Sea (Ferreira et al., 2011). In the first study of this dissertation (I), nutrient runoff, namely phosphorus and nitrogen runoff are affected by fertilizer use and drainage choice. It is assumed that surface drainage leads to lower nitrogen and higher phosphorus runoff than subsurface drainage if the same amount of fertilizer is applied to the field (Turtola and Paajanen, 1995). Also in Study I biodiversity impacts are measured using a bird species density as an indicator of biodiversity. Bird species density is positively affected by surface drainage ditches that act as habitats for many bird species in Finland (Vepsalainen et al., 2010). The impact of surface drainage on bird species density is assumed to be further affected by the location of a surface drained area in a landscape.

3.2 Environmental externalities and policy instruments

Because of the public good characteristics of the unintentional environmental outputs studied in this dissertation, the markets for such outputs often have to be facilitated by government authorities to improve social welfare. Fixed market incentives such as taxes and tax credits are feasible options when the real externalities are known. However, in the case of public goods and bads, their true aggregate utilities may be difficult if not impossible to define with adequate accuracy to set cost-effective tax-based policies (Samuelson, 1954). In such cases it may be justified to use cap (and trade) based policy instruments to ensure that the production of public goods/bads does not exceed/surpass some critical level.

In paper I, it is assumed that the damage cost for per unit nutrient runoff is defined but the benefits of biodiversity are unknown. In this case we are interested in what are the social costs to increase biodiversity when nutrient runoff damages are taken into account. In articles II and III where bioenergy, namely biofuel is produced from agricultural biomass, it is assumed that biofuel is used to replace fossil fuels. Instead of GHG emission cost, we use the concept of GHG emission benefit that results from the substitution of fossil fuel for biofuel. This benefit is positive if the emissions of biofuel are lower than the emissions of fossil fuel. In both papers II and III the externality costs of GHG emissions are assumed in twofold fashion both unknown and known. This allows us to define optimal taxes, and also to study the costs to increase GHG benefits or the profitability of bioenergy production under emission constraints. Studies II and III also assess the impacts of actual real-life biofuel and energy policies. In paper IV where GHG induced climate change is an input of production, the externality costs can be perceived as the total change in cereal grain production. In this case the study is for entire Russia and therefore it is inevitable that the impacts of climate change on cereal grain production vary among different regions.

What comes to the other spatial aspects of environmental externalities studied in this dissertation, a unit of GHG emissions can be understood to have a similar effect on the atmosphere regardless of the location of the pollution source. Whereas, alterations in agricultural biodiversity and landscape can be seen as phenomena that are more sensitive to spatial aspects such as scale and connectivity. Due to these spatial features of environmental impacts, it can be claimed that it may be more justified to define a per unit social price on nutrient runoff to a certain water body, or on global GHG emissions, than for example on increment in local species diversity. Also a single global price on GHG emissions, may be more reasonable policy option than multiple national emission quotas (Weitzman, 2015).

3.3 On the methods applied in the studies

The first three papers (I,II,III) are based on microeconomic theory, optimization and empirical numerical applications. The last study (IV) relies more on econometric methodology and applies a fixed-effect model and a long difference model to estimate how changes in climate can affect cereal grain yields. In this case yields represent farmers profits assuming that farmer maximizes the production. Fixed effects model takes into account annual weather variation, whereas long-difference (LD) model accounts for longer term variation in climate and thus allows the farmers to adapt to the climate change (See Table 1 for methodologies used in the studies)

In this dissertation it is mainly assumed that the information about the markets in the absence of externalities is perfect. Whereas, the information assumptions about the externality costs and benefits are twofold; the same externality can be analyzed both by maximizing social welfare while assuming that the impact on utility is explicitly defined, and then by assuming the opposite and employing an abatement/incremental cost approach, or an environmental constraint. The combination of these assumptions is useful especially when assessing the impacts of actual existing policy instruments, because it allows us to study these policies from different economic and environmental objectives. Also in essay I, a case where there are two externalities and a cost or benefit is certainly known for only one of them is studied employing an abatement/incremental cost approach. In this case we assume that we know the damage caused by nutrient runoff, whereas the biodiversity benefits resulting from surface drainage cannot be defined due to the lack of convincing benefit estimate or function. The social costs to increase biodiversity, when nutrient runoff damages are taken into account, are the social incremental costs of biodiversity. In Finland the costs to increase biodiversity by establishing agricultural biodiversity zones, and the costs to increase biodiversity and decrease nutrient runoff by farmland allocation have been assessed by Miettinen et al. (2012) and Helin et al. (2013). These studies do not take into account the costs or benefits resulting from nutrient runoff or biodiversity but the cost to increase or decrease them. Lankoski and Ollikainen (2003) have used an opposite approach to maximize social welfare from agricultural production, when an exogenous social cost and price are defined for nutrient runoff and biodiversity respectively. The social incremental cost approach applied in study I is a combination of these two approaches where the social cost or price can be defined for some but not for all of the unintended agricultural outputs.

4 Summaries of the studies

4.1 Essay 1. Socially optimal drainage system and agricultural biodiversity: A case study for Finnish landscape

In the first paper we examine the socially optimal drainage choice (surface/subsurface) for agricultural crop cultivation in a landscape with different land qualities (fertilities) when private profits and nutrient runoff damages are taken into account. We also study the measurable social costs to increase biodiversity by surface drainage when the locations of the surface-drained areas in a landscape affect the provided biodiversity. We develop a general theoretical model based on a model by Lankoski and Ollikainen (2003) and apply it to empirical data from Finnish agriculture. We find that for low land qualities the measurable social returns are higher to surface drainage than to subsurface drainage, and that the profitability of subsurface drainage increases along with land quality. The measurable social costs to increase biodiversity by surface drainage under low land qualities are negative. For higher land qualities, these costs depend on the land quality and on the biodiversity impacts. Biodiversity conservation plans for agricultural landscapes should focus on supporting surface drainage systems in areas where the measurable social costs to increase biodiversity are negative or lowest. Farmland bird species are used as an indicator for agricultural biodiversity. This is partly due to availability of bird abundance data but also other arguments support this indicator selection. The number of bird species serves as proxy for aesthetic, recreational and intrinsic valuation of biodiversity, since most bird species in Europe are neither harmful nor directly beneficial for farming and are a subject of birdwatching. In the agricultural landscapes birds lie at a high level in the food chain, and therefore they are highly sensitive to agricultural practices which cause variations in the lower trophic levels (Mouysset et al., 2012). Finally, because the abundance of bird species is a good indicator of changes in the overall conditions of ecosystems which are difficult and expensive to measure directly, farmland birds is the only biodiversity group on the list of EU's Structural and Sustainable Development Indicators. If other indicator was used for biodiversity, or if the spatial scale for bird species abundance data was different, or if the model was applied for different agronomic conditions, this could impact the results on the social profitability of different drainage systems. However, the general analytical framework presented in the study and the theoretical insights would still apply.

4.2 Essay 2. Imported palm oil for biofuels in the EU: Profitability, greenhouse gas emissions and social welfare effects

In the second paper we examine the social desirability of renewable diesel production from imported palm oil in the EU when greenhouse gas emissions are taken into account. Using a partial market equilibrium model, we also study the sectoral social welfare effects of a biofuel policy consisting of a blend mandate in a small EU country (Finland), when palm oil based diesel is used to meet the mandated quota for biofuels. Loosely following the market frameworks of Cui et al. (2011) and de Gorter and Just (2010) we develop a market equilibrium model for three cases: i) no biofuel policy, ii) biofuel policy consisting of socially optimal emission based biofuel tax credit and iii) actual EU biofuel policy. Our results for the EU biofuel market, Southeast Asia and Finland show very little evidence that a large scale use of imported palm oil in diesel production in the EU can be justified by lower greenhouse gas emission costs. Cuts in emission costs may justify extensive production only if low or negative land-use change emissions result from oil palm cultivation and if the estimated per unit social costs of emissions are high. In contrast, the actual biofuel policies in the EU encourage the production of palm oil based diesel. Our results indicate that the sectoral social welfare effects of the actual biofuel policy in Finland may be negative and that if emissions decrease under actual biofuel policy, the emission abatement costs can be high regardless of the land use change emissions.

4.3 Essay 3. Economics of bioenergy production from agricultural biomass with application to herbaceous field crops

The third paper of this dissertation sets out a simple spatial model to study the economics of bioenergy production from agricultural biomass, when bioenergy can be produced simultaneously from one or two biomasses with two market outcomes (monopsony/bilateral monopoly). Also optimal carbon policy (tax credit and minimum emissions reduction) design and the impacts of suboptimal and actual policy are studied. The model is applied numerically to agricultural biomass and lignocellulosic ethanol production in Finland. The model and results implicate that market failures or suboptimal policies can result in significant surplus and welfare losses. The simulation results show that ethanol production from agricultural biomass in Finland can be profitable, even without biofuel policy, but only when effective biomass conversion technology is applied to ethanol production. The possibility to use a mixture of two biomasses in bioenergy production allows the bioenergy plant to adapt to given policy by producing an economically optimal bioenergy mix. Minimum emission reduction constraints may reduce bioenergy production compared to the outcome without policy, and have ambiguous land use impacts.

4.4 Essay 4. Impact of Climate Change on Cereal Grain Production in Russia

The fourth paper analyses the effects of climate change on cereal grain production in Russia. The study focuses specifically on cereal grain production, because cereal grain crops, especially wheat, represent the most economically important agricultural products in Russia. Cereal grain yields are assumed to reflect the economic viability of grain cultivation. Following the studies by Burke and Emerick (2016) and Deschenes and Greenstone (2007) the climate change impacts are identified from regional data through short-term weather variation (fixed-effects model) and midterm changes (long-difference model) in weather variables which enable us to address potential adaptations to climate change. The results of the study suggest that in the short term the warmer and longer growing seasons are beneficial for cereal grain yields in colder regions, whereas the impact is reversed for warmer regions with higher cereal grain yields. The increase in winter temperatures has a significant positive impact on grain yields in both models. The results for precipitation are less robust, but they intuitively suggest that an increase in precipitation is detrimental to cereal grain production during the harvest season. In the model excluding adaptation, the predicted climate change will impact the total cereal grain yield in Russia by -15 % to -7 % by 2050 depending on the underlying climate scenario. Based on a less robust model allowing for mid-term adaptation, the predicted climate change will increase the cereal grain yields in Russia by 1–14 %, respectively. These results suggest that excluding the possible adaptation measures from the study can exaggerate the negative climate change impacts on agriculture. Nevertheless, these results also suggest that the maximum benefits to yields are obtained in a mild warming scenario (of not more than 2 °C) while warming beyond that will be less beneficial, and the total impact is highly dependent on how warming is distributed seasonally.

5 Summary and conclusions

The main objective of this thesis was to study the welfare impacts of the production of different agricultural commodities and agricultural production methods, when environmental externalities were taken into account. Also the optimal policies targeted to externalities, and costs to increase or decrease the unintended environmental public goods or bads causing the externalities were examined. The aim of this dissertation was also to apply the joint production theory to typical environmental externalities related to agricultural production.

The results of the studies show that the scope of an agricultural externality often depends on the local production characteristics and underlying assumptions, such as those related to land use, and the utility and damage functions. The studies also indicate that policies targeted to agri-environmental externalities should be designed holistically for example by taking into account entire landscapes or sectors, but at the same time by relying on heterogenous policies within these entities. Also Shortle and Abler (2001) state that the choice of a policy instrument base and uniformity can significantly impact the cost effectiveness of an agri-environmental policy. Lankoski and Ollikainen (2003) reach the same conclusion on optimal policies for environmental externalities of agricultural production in Finland. Finally, other possible market failures, such as spatial monopsonies should be taken into account in the policy design for agricultural supply chains.

The first three papers all present a comparison of cases where either the externality cost or benefit is know, or where it cannot be explicitly defined. As stated earlier the combination of these assumptions is useful especially when assessing the impacts of actual existing policy instruments, because it allows us to study these policies from different economic and environmental objectives. Using both of these assumptions simultaneously in paper I, we were able to examine a case where there are two externalities and a cost/benefit is certainly known for only one of them. This way we were able to study the social costs to increase biodiversity by surface drainage when nutrient runoff damages were taken into account in the social cost. Finally the last study shows that the impact of an unintended public good (or bad) such as climate change can depend a lot based on the characteristics of the consumer, and that the adaptation options should be taken into account in the definition of the costs and benefits.

The scope of the dissertation was limited to a few environmental goods and bads, and the empirical data used in the analysis was mainly based on Finnish or other local averages. Therefore very detailed or explicit policy recommendations cannot be based on the results of this study. However, the presented methodological approaches applying the theory of joint production are applicable also for other spatial and thematic contexts. Approaches based on joint production theory could further be used to model interdependencies between agriculture and ecosystem services (Huang et al., 2015; Swinton et al., 2006)

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